Autonomous Solar Pool Heater

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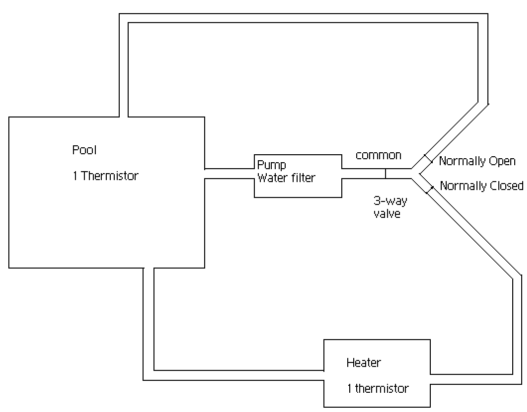
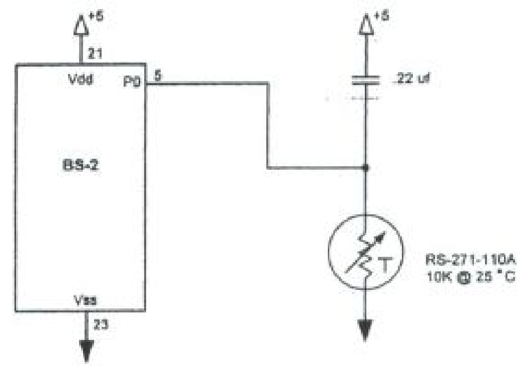
Introduction

Anyone with a gas or electric pool heater knows that heating a pool up by just a few degrees can be quite expensive. Solar heaters can be a great low cost way of heating up a pool but they come with their own set of challenges. A solar heater without a proper control system can be wasteful and ineffective. If a pump for a solar heater is left on during a cold night, it will actually lower the pools temperature through convection. With humans constantly away at work or busy, it can be too difficult for them to monitor weather the system should be on or off. Our project will develop a smart system which will make decisions and control the flow of water based on temperature. The system will consist of two thermistors, a three way solenoid valve, a water pump and a solar heater all interfaced with our BS2 Controller. Thermistor T1 will be placed in the pool. Thermistor T2 will be placed in the solar fixture. The pump will send water through the filter, and into a three way valve. Normally, water will flow through the NO port of the valve directly back into the pool. As T2 becomes greater than T1 +10°C, the valve will actuate, sending water through the solar fixture and heating the pool. If T2 falls below the lower threshold of T1 + 8°C, the valve will revert back to its orginal state and send water back into the pool. This will ensure that the solar fixture can not cool down the pool on a cold day.



Theory and mathematical background

For temperature measurement two separate RC circuits are used, with thermistors as variable resistors.



In order to protect BS2 we use 220Ω resistors

C = 0.1 F

For calibration of the AD592 thermistors we use the following formula relating the temperature to the time measured by RCTIME :

$$RCtime = \frac{Constant}{T(K)}$$

In order to find this constant we can rearrange the equation to solve for the constant with a know Temperature value. Typically an ice/water bath can be used because it is know to be 0°C. However after performing the calibration, we found the results to be inaccurate at our operating range. This is because Thermistors are nonlinear. Because they can be assumed to be linear within a smaller operating range, we calibrated at 20°C which is within our operating range. We used a digital temperature sensor which was already calibrated as the basis for our calibration. Each Thermistor RC Circuit was calibrated separately due to tolerances in resistance and capacitance values.

At 20°C we obtained the following RCTIME values:

RCtime1 = 833
RCtime2 = 858

Than we used these values to calculate the constants of the two circuits (outside of basic stamp):

$C_1 = 833 \cdot 293(K) = 244049$
$C_2 = 858 \cdot 293(K) = 251394$

The constant values exceed the word size variable for BS2 (0-65536), therefore we divided C_1 and C_2 by 4:

$$C_1 = \frac{244049}{4} = 61017$$

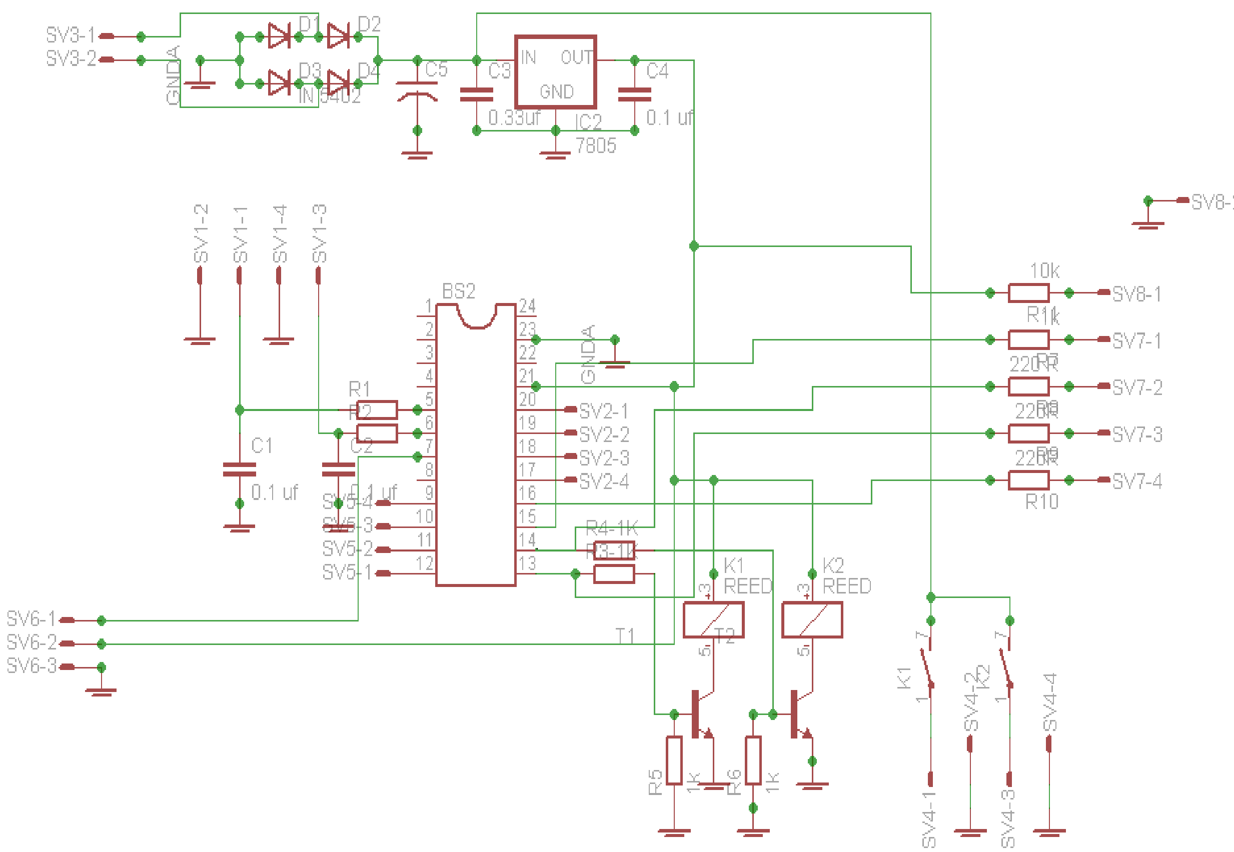
$$C_2 = \frac{251394}{4} = 62849$$

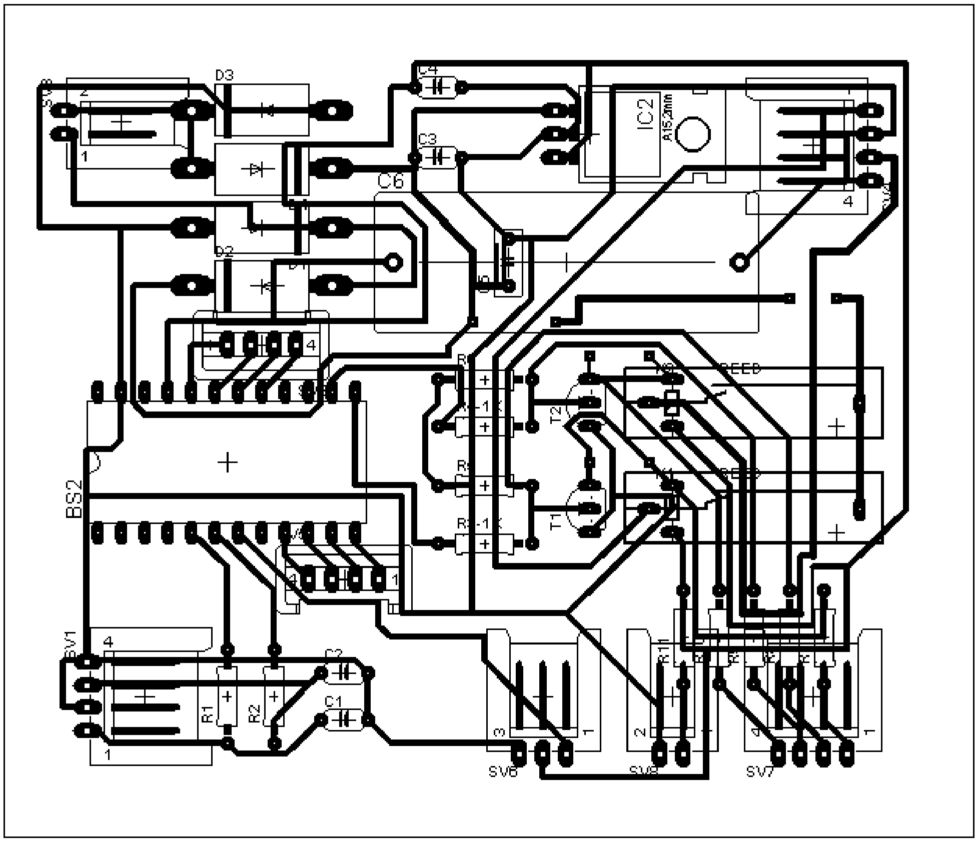
To maintain an accurate calculation, the RCtime values divided by four within the Basic Stamp code. Temperature Values in °C are then calculated using the following formula

$$T_1 = \frac{C_1}{RCtime_1} - 273$$

$$T_2 = \frac{C_2}{RCtime_2} - 273$$

Electronic circuit





Bill of material and prototype cost estimate

Quantity	Material	Estimated cost	Mass production per unit
1	3 way Solenoid Valve ½" NPT	140$	60$
1	Solar Heater (optional)	150$	80$
50 ft	Tubing	10$	3$
1	Basic Stamp 2	50$	25$
2	Relay 120V (15A)	200$	75$
2	Thermistor AD592	30$	3$
2	Transistor	1$	0.25$
11	Resistors	2$	0,5$
5	Capacitors	10$	4$
1	Voltage Regulator IC	2$	1$
4	Diode	5$	2$
1	110/24-0 Transformer	6$	3$
	PCB Production		3$
	Labor cost		30$
Total (with Solar Heater)		606$	290$
Total		456$	210$

Analysis advantages/disadvantages

Solar heaters have a clear cut advantage over Gas and Electric heaters for long term Cost. For example, the amount of energy needed to heat a 7,500 gallon pool by one °F would be 60,000 BTU's. A cubic foot of gas cost $2.34 on average and has 1,000 BTU's of energy. At that rate it would cost $140 per °F or $252 per °C. At this rate it could cost thousands of dollars just to keep a pool at a comfortable temperature for the summer. In contrast, the cost of running a solar heater is dictated by how many hours the pump is running. The pump will only go on when the temperature of the solar panel is significantly warmer than the pool temperature. This threshold could also be modified to balance energy cost and effectiveness.

Solar heaters are also better for the environment. While natural gas is a clean burning fuel in comparison to coal and gasoline, it still emits greenhouses gases. Solar heaters do not.

One disadvantage to using solar power is that the amount of heat energy generated in a given day is beyond your control. For example, a gas heater could be turned on at will, while with solar energy, it will only work on a sunny day. A solar heater will provide less power than an electric heater. This means it will take more time to heat up a pool compared to gas heaters.

Using a control system for a solar heater provides a big advantage over a solar heater than is constantly left running. A solar heater without a proper control system can be wasteful and ineffective. If a pump for a solar heater is left on during a cold night, it will actually lower the pools temperature through convection. With humans constantly away at work or busy, it can be too difficult for them to constantly monitor weather the system should be on or off. A typically pool heater with control circuits and valves costs approximately $4000. The estimated cost of our model is under $1000.

The model uses an LCD to display both Pool and Heater temperature. It also uses LEDs to show if the pump is on or not. This allows the system to be run without a computer. A disadvantage of our design is that the temperature threshold is hardcoded and therefore doesn't allow the user to modify it without a computer. A future design may include a potentiometer or button to allow the user to modify this value without the need for a computer.

PBASIC Code

```
' =========================================================================
'
'   File....... Mechatronics Final Design Project
'   Purpose.... Control System for Solar Pool Heater
'   Author..... Damian Shchur, Sidharth Patel, Daniele Shaglia
'   Updated.... 12/19/11
'
'   {$STAMP BS2}
'   {$PBASIC 2.5}
'
' =========================================================================


' -----[ Program Description ]---------------------------------------------
' This program monitors the temperature of a pool (PoolTemp) and the Temperature of a solar water heater (SolarTemp).
' In order to increase Efficiency and save money (electricity costs) water is only pumped through the solar heater
' if T1 = T2 + DeltaC.  DeltaC is a constant representing degrees C and can be chosen by the user.  Note that a high DeltaC value will turn
' use less energy, but may not heat the pool as effectively; while a low DeltaC value will use more energy and will likely heat
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' the pool quicker

' -----[ Revision History ]------------------------------------------------


' -----[ I/O Definitions ]-------------------------------------------------
ThermPool    PIN      0
ThermHeater  PIN      1
PumpRelay    PIN      8
ValveRelay   PIN      9
LCD          PIN      2

' -----[ Constants ]-------------------------------------------------------

C1      CON       61017           'Calibration Constant for PoolTemp Calculation.  244069/4 (As not to
exceed max size 2^16)
C2      CON       62849           'Calibration Constant for HeaterTemp Calculation.  251394/4 (As not to
exceed max size 2^16)
DeltaC  CON       10              'User Defined Constant to control Efficiency, Effectiveness.  Must be
greater than 4


' -----[ Variables ]-------------------------------------------------------
PoolTemp         VAR Word
HeaterTemp       VAR Word

' -----[ EEPROM Data ]-----------------------------------------------------


' -----[ Initialization ]--------------------------------------------------

Reset:


' -----[ Program Code ]----------------------------------------------------

Main:
   LOW PumpRelay                              'Start with Pump and Valve Off
   LOW ValveRelay


DO
  HIGH ThermPool                              'Set high to charge capacitor
  HIGH ThermHeater                            'Set high to charge capacitor
  PAUSE 1                                     'Allow Capacitor to fully charge
  RCTIME ThermPool, 1, PoolTemp               'Measure RCTime value of pool
  RCTIME ThermHeater, 1, HeaterTemp           'Measure RCTime value of heater
  PoolTemp= PoolTemp/4                        'Must be divided by 4 as is the calibration constant
  HeaterTemp= HeaterTemp/4                    'Must be divided by 4 as is the calibration constant
  PoolTemp = C1/PoolTemp-273                  'Calculate Degrees C
  HeaterTemp = C2/HeaterTemp-27               'Calculate Degrees C
  DEBUG CLS, ? PoolTemp
  DEBUG ? HeaterTemp
```

```
   SEROUT 2,84, [22,12]                              'Clear LCD Display
   PAUSE 10                                          'Allow time to clear
   SEROUT 2,84, ["Pool T = ",DEC PoolTemp," C", 148,"Heater T = ", DEC HeaterTemp, " C"]   'Display both
Temperatures on LCD
   PAUSE 1000                                        'Allow time for display (serial commands)
   IF HeaterTemp > PoolTemp + DeltaC THEN            'Logic to turn pump on (compares both temperatures)
     HIGH ValveRelay                                 'If true activate relays, turn on valve and pump
     HIGH PumpRelay
     PAUSE 2000
   ELSE IF HeaterTemp < PoolTemp + DeltaC - 2 THEN              'Lower threshold to prevent bouncing
     LOW PumpRelay                                              'Turn off Pump and Valve
     LOW ValveRelay
     PAUSE 2000
   ENDIF
LOOP
```